Open Access

*Original Paper*
*J. Glob. Innov. Agric. Sci., 2026, 14(2):363-372*
*ISSN (Online): 2788-4546; ISSN (Print):2788-4538*
*DOI: https://doi.org/10.22194/JGIAS/26.1647*
*http://www.jgiass.com*

Society for Innovative Agriculture

# Inheritance and Gene Action of Salinity-Resistance-Related Traits in F1 Crosses of Resistant and Sensitive Maize

Kelik Perdana Windra Sukma[1], Budi Setiadi Daryono[2*], Diah Rachmawati[2] and Purnomo[2]

[1]Doctoral Program, Faculty of Biology, Universitas Gadjah Mada, Yogyakarta, Indonesia; [2]Faculty of Biology, Universitas Gadjah Mada, Yogyakarta, Indonesia
[*]Corresponding author's e-mail: bs_daryono@mail.ugm.ac.id

Maize is the third most cultivated cereal crop, following rice and wheat, and it is significantly affected by salinity stress. Maize performance under salinity stress can be improved by breeding. A thorough understanding of the traits associated with salinity stress, its inheritance, and gene action is needed for developing resistant varieties. This research aimed to study the inheritance and gene action of traits related to salinity stress in hybrid maize F1 crossbreed of 'Elos' and 'Bonanza' (BE & EB). 'Elos' was a salinity-resistant maize, 'Bonanza' was a salinity-sensitive maize, BE was F1 crossbreed with 'Bonanza' as the female and 'Elos' as the male and EB were the reciprocal. These maize varieties were planted in polybags containing a soil-sand mixture with a total weight of 10 kilograms (5 kg soil and 5 kg sand). Salinity levels were established by adding NaCl until the electrical conductivity (EC) reached 3 dS/m (low salinity) and 6 dS/m (moderate salinity); the control group was not treated with salt. The polybags were arranged in a randomized complete block design (RCBD) based on salinity levels and cultivar treatment, with each treatment replicated 20 times. The characters observed included plant height, stem diameter, leaf number, leaf length, leaf width, ear height, anthesis time, silking time, harvesting time, ear length, ear diameter, ear weight, seed number, the weight of 100 seeds, and total seed weight. The traits related to salinity were analyzed using a correlation test, and salinity resistance was assessed through the salinity tolerance index (STI). The indices were compared using ANOVA and Duncan's post hoc test, utilizing IBM SPSS version 25. This study also determined heterosis effects and gene action. The results indicated that the characteristics associated with salinity resistance in hybrids were inherited predominantly from the salinity-resistant parent, Elos (partially and over dominance), especially at low and medium salinity. At moderate salinity, the dominance of parent E remains dominant in most characters, while parent B has an effect on ear length and weight of one hundred seeds. This change in dominance reflects a shift in gene action due to increased salinity stress. Based on heterosis values, hybrids EB were better than BE in low and moderate salinity conditions, with positive values on production characteristics such as plant height, stem diameter, and seed weight. However, negative heterosis in anthesis, silking, and harvest time showed a decrease in salinity resistance compared to the parent. Gene action in EB and BE hybrids in salinity stress shows the dominance of additive gene action with complementary and duplicate epistasis effects. At moderate salinity stress, there was a change in gene action from complementary to duplicate in some characters, reflecting changes in resilience mechanisms due to increased stress. Overall, salinity resistance expression in EB and BE is controlled by many genes, with inheritance patterns shifting with stress levels. The variations in heterosis values and gene action highlighted the complex structure and interactions of genes involved in salinity resistance.

**Keywords:** Salt accumulation, soil degradation, abiotic stress, gene action, heterosis, inheritance, toxicity.

## INTRODUCTION

Salinity is one of the abiotic stresses that cause land degradation and decreased crop production. Salinity causes a decrease in production by 10-25% in about 2000 cultivated lands (Shahid et al., 2018). Indonesia also has salinity problems, with a coastline of 99,093 km and 13,2 million hectares of land area affected by salinity (Arif, 2021; Pavuluri et al., 2014; Suprianto et al., 2010). The affected land will increase, especially in coastal areas, due to rising sea levels, seawater intrusion, and overexploitation of groundwater (Gama et al., 2007; Ismail, 2007; Putra & Indradewa, 2011).

Sukma, K.P.W., Daryono, B.S., Rachmawati, D., & Purnomo. 2026. Inheritance and Gene Action of Characters Associated to Salinity Resistance in F1 Crossbreed of Resistant and Sensitive Maize. *Journal of Global Innovations in Agricultural Sciences, 14*(2), 363-372.
[Received 28 Feb 2025; Accepted 31 Aug 2025; Published 11 Jan 2026]

Attribution 4.0 International (CC BY 4.0)

Salinity has a major impact on agricultural land, especially in areas with high levels of salinity on agricultural land is significant, especially in areas with high salt levels in the soil or irrigation water. Salt accumulation can lead to degradation of soil structures, where soil particles become denser and less porous, thus inhibiting water infiltration and air circulation (Han & Wang, 2023; Xing et al., 2025). The high sodium content in the soil can replace calcium and magnesium, causing the soil to become hard and difficult to cultivate. As a result, soil fertility decreases due to the disruption of soil microorganism activity and the reduced availability of essential nutrients for plants (Hailu & Mehari, 2021; Mohanavelu et al., 2021; Yahaya et al., 2023).

Salinity also has impact on crops such as soybeans (David & Abdurrahman, 2021), peanuts, mungbean (Fatikhasari et al., 2022; Meena et al., 2022), wheat (Seleiman et al., 2022), rice (Coca et al., 2023), sorghum (Dehnavi et al., 2024), and maize (Sousa et al., 2022). High salt levels in soil or irrigation water cause osmotic stress, which inhibits the absorption of water by plant roots and results in the dehydration of plants even when water is available (Ozturk et al., 2021). The accumulation of salt ions such as sodium ($Na^+$) and chloride ($Cl^-$) in plant tissues causes toxicity and nutrient imbalance that impairs physiological functions, such as disturbances in photosynthesis and metabolism. Those make plant growth is stunted, leaves turn yellow, production decreases, and in more severe cases, plants can die before reaching harvest time (Alghamdi, 2024; Singh et al., 2025; Yang et al., 2011). Maize, which is the third cereal crop (after rice and wheat) cultivated in the world and a major multipurpose crop for food, feed, and energy (Ramazan et al., 2023), is also affected by salinity stress. All phases of maize growth, from germination to production (Carpıcı et al., 2009; Dachlan et al., 2013; Hussain et al., 2010; Khayatnezhad & Gholamin, 2011; Nawaz et al., 2020; Shtereva et al., 2015) are reduced by salinity stress. The levels of chlorophyll and ions in maize plants changed with salinity stress treatment (Aliu et al., 2015; Hoque et al., 2015; Utama & Haryoko, 2020). The effect is also related to the genetic structure of maize plants. Some genetic material has been detected related to salinity resistance. Balkrishna and Shankarrao (2013) used 11 RAPD primers and found 10 polymorphic bands related to DNA salinity resistance. Tahir and Maeruf (2016) used 13 SSR primers and obtained 46 polymorphic alleles related to salinity resistance. Ding et al. (2009) stated that there were changes in the expression of 98 miRNAs from 27 miRNA families of plants, indicating that miRNAs are related to metabolic, morphological and physiological adaptation regulation. Chaged expression of *ZmNHX* (Zörb et al., 2005), *ZmHKT* (Cao et al., 2019; Jiang et al., 2018), *ZmSOS* (Bosnic et al., 2018) and *ZmSKOR* (Li et al., 2020) genes also occurred in maize in salinity treatment. These genes are associated with transport ions and proteins in process of $Na^+/K^+$ homeostasis. Increasing the resistance of corn plants to salinity can be done by breeding. One of the sources of germplasm for saline-resistant corn plants is local maize. There are 16 local maize in Madura Islands, Indonesia (Amzeri et al., 2011) and 'Elos' is the best salinity tolerance maize (Sukma et al., 2018), but the production is very low, which was less than 2 tons per hectare. If 'Elos' is crossed with other varieties, the salinity resistance germplasm of 'Elos' is expected to be inherited to the offspring to become a salinity-tolerant hybrid variety, and also has other advantages, such as high production, protein, or sugar content.

Crossbreed of 'Elos' with varieties that are more sensitive to salinity stress need to be done to understand the character and the inheritance to develop resistance varieties effectively and efficiently. 'Bonanza' is one of the sweet corn that is widely cultivated by farmers and is sensitive to salinity. The crossbreed between 'Elos' and 'Bonanza' is expected to produce a hybrid sweet corn that is more tolerant of salinity. The breeding progress can be observed through offspring performance. The performance was determined by the characteristics and evaluated by genetic variability and combining ability approaches (Aslam et al., 2015; Cao et al., 2019; Cui et al., 2015; Fang, Fu, et al., 2024). In this study, the performance determined by characteristics of growth, production and salinity tolerance index (STI). The inheritance was explained by comparing the correlation coefficient from correlation between the characteristics and increased salinity level maize character and increased salinity level. The inheritance is also explained by heterosis and gene action based on STI value. An understanding of gene action (dominance, additives, and epistasis) as well as heterosis is important in the breeding of resalable maize varieties because it determines how resistance traits are inherited and expressed.

## MATERIALS AND METHODS

***Seeds material*:** The seeds used in this study were salt-resistant maize, 'Elos' (E) from mass selection of local maize and salt-sensitive maize, 'Bonanza' (B) produced by PT. East West Seed Indonesia (Sukma et al., 2025) and its hybrids F1 crossbreed reciprocal/EB and BE). EB was a crossbreeding of female 'Elos' and male 'Bonanza', and BE was its reciprocal.

***Media preparation*:** Polybags were filled with 10 kilograms of soil-sand mixture (1:1). The media was added salt (NaCl) until the EC became 3 ds/m (low salinity) and 6 dS/m (moderate salinity), and the non-saline media was not added salt.

The weight range of salt (mNa) added to the media can be formulated as follows:

$$mNa = C \times EC \times fc$$

with mNa = weight of added salt (gr)

C = constant (640 for EC < 5 dS/m and 800 for EC ≥ 5 dS/m)

EC = desired salinity level

*fc* = water volume of field capacity

The salinity level used at the beginning of planting is in the range of 0, 3, and 6 dS/m. The salinity determined monthly during the treatment period. It was determined by mixing 10 g of soil with 50 ml aquades, than measured the EC solution using EC meter HANNA HI9813-5 after sediment settle. Salt can be added if the medium with a salinity of 3 dS/m becomes less than 2 dS/m and in media with a salinity of 6 dS/m becomes less than 4 dS/m.

***Planting and maintenance*:** Seeds from 4 cultivars are sown in petri dishes, which have been filled with wet wipes for 7 days. On the seventh day after seeding, the shoots are planted into polybags. The polybags are placed on field (daily temperature 30-45ºC, humidity 70-80%), were randomly arranged according to the Randomized Complete Block Design (RCBD) experiment with two factors, namely cultivars (E, B, EB, BE) salinity level (0, 3 and 6 dS/m) and cultivar. Each combination of treatments was replicated 20 times.

The plants were watered every two days, and fertilizer (4 g NPK manure per plant) was added 10 and 30 days after planting.

***Observation and analysis*:** The characteristics observed were plant height, stem diameter, leaf number, leaf length, leaf width, ear height, anthesis time, silking time, harvesting time, ear length, ear diameter, ear weight seed number, weight of 100 seeds, and total weight of seed. The characters related to salinity are determined by correlation test.

Salinity resistance is determined by salinity tolerance index (*STI*) of the characteristics by comparing character value on particular treatment and on control (Khayatnezhad & Gholamin, 2011).

$$\text{STI (\%)} = \frac{\text{character on particular treatment}}{\text{average character on control}} \times 100\%$$

The *STI* of all characters were analyzed using Analysis of Variance (ANOVA) to compare the resistance level of each cultivar to salinity treatment. Inheritance is determined based on gene action and heterosis.

Heterosis was calculated based on STI value of characteristics. Heterosis consists of midparent (hMP) and best parent/heterobeltiosis (hHP). $hMP$ is calculated by comparing the average value of the appearance of the F1 plant genotype ( $\mu F1$) with the average value of both parents ($\mu MP$). Heterobeltiosis ($hHP$) is calculated by comparing the average value of the appearance of the F1 genotype ($\mu F1$) with the average value of the highest parent ($\mu HP$) (Effa et al., 2016)

$$\text{hMP (\%)} = \frac{\mu\text{F1} - \mu\text{MP}}{\mu\text{MP}} \text{ x } 100\%$$

$$\text{hHP (\%)} = \frac{\mu\text{F1} - \mu\text{HP}}{\mu\text{HP}} \text{ x } 100\%$$

Gene action was calculated based on the degree of dominance (Petr & Frey, 1966). Degree of dominance (*HP*) is calculated by:

$$\text{HP} = \frac{\mu\text{F1} - \mu\text{MP}}{\mu\text{HP} - \mu\text{MP}}$$

Genes that control quantitative characters were classified as follows: hp = 0(no dominance/nd); 0<hp<1 (partially positive dominance/ppd); -1<hp<0 (partially negative dominance/pnd); hp=1 / -1 (perfectly dominant/pfd); HP > 1 (over dominant positive/odp); HP < -1 (over dominant negative/odn).

Interaction and number of genes controlling the plant characters were determined by skewness and kurtosis values (Dasriani et al., 2020; Wibowo, 2018). Skewness and kurtosis are calculated using the formulas available in Excel 2019. Skewness (Sk) can show epistasis affected expression of character. Sk = 0, normal distribution, gene action additive. Sk>0, abnormal distribution, gene action is additive and there is complementary epistasis. Sk<0, abnormal distribution, gene action is additive and there is duplicate epistasis. Kurtosis (Kc) can show number of genes that control a character. If Kc>3, the character is controlled by a few genes. If Kc<3, the character is controlled by many genes.

## RESULTS

***Characters associated to salinity resistance*:** Correlation test aims to identify the relationship between increased salinity levels and the characteristics of hybrid maize and its parents. Table 1. showed that almost all characters were negatively correlated with the increase in salinity, indicating that salinity decreased the performance of maize. A positive correlation in flowering times indicates that salinity delays flowering time, and negative in the harvest time of hybrid and parent E maize shows the accelerating. The characters of hybrid EB maize were generally insignificantly correlated with salinity except for plant height, flowering time, and a hundred seed weight. Meanwhile, in hybrid BE, most of them were significantly correlated except for stem diameter, number of leaves, ear height and silking time. Most of Parent E characters were significantly correlated with salinity except for number of leaves, anthesis time and harvesting time, meanwhile all characters of parent B were significant. The lower correlation value of parent E than B showed that Parent E was more resistant to salinity stress. Significant correlation values indicate that the character is sensitive to increasing salinity levels, while non-significant correlations suggest that the character is more stable or more resistant to salinity stress. In the EB hybrid, 11 characters were relatively stable against increasing salinity levels, such as stem diameter, number of leaves, leaf length, leaf width, ear height, harvesting time, ear weight, number of seeds, and total seed weight. In the BE hybrid, 4 characters were stable, namely stem diameter, number of leaves, anthesis time, and harvesting time. The

stability of these characters was better than in both parent lines, while the E parent showed stability in only 3 characters, and all characters in the B parent showed significant or highly significant correlations with the increasing of salinity.Based on the value of the correlation coefficient (*r*), almost all the characters in the hybrid were closer to the parent E than the parent B, indicate the dominance of parent E to B in hybrids characters associated with salinity stress. Plant height of hybrid EB was closer to the parent E and BE was closer to the parent B, while flowering time character of hybrid EB was closer to parent B and BE hybrid is closer to the parent E. It was suspected that there was maternal effect on the characters of the salinity stress.

**Table 1. The correlation between maize character and increased salinity level.**

| Characters | *r* (coefficient correlations) | | | |
|---|---|---|---|---|
| | EB | BE | E | B |
| Plant height (ph) | -0.259** | -0.502** | -0.340** | -0.576** |
| Stem diameter (sd) | 0.091 | -0.022 | -0.306* | -0.506** |
| Number of leaves (ln) | -0.059 | -0.100 | 0.152 | -0.592** |
| Leaf length (ll) | -0.134 | -0.355** | -0.350** | -0.519** |
| Leaf width (lw) | -0.216 | -0.415** | -0.317* | -0.597** |
| Ear height (eh) | 0.081 | -0.285* | -0.360** | -0.589** |
| Anthesis time (at) | 0.448** | 0.221 | 0.205 | 0.469** |
| Silking time (st) | 0.454** | 0.279* | 0.280* | 0.511** |
| Harvesting time (ht) | -0.034 | -0.051 | -0.040 | 0.431** |
| Ear length (el) | -0.282 | -0.564** | -0.445** | -0.683** |
| Ear diameter (ed) | -0.230 | -0.454** | -0.300* | -0.706** |
| ear weight (ew) | -0.190 | -0.408** | -0.373** | -0.529** |
| Number of seeds (sn) | -0.092 | -0.308* | -0.309* | -0.594** |
| 100 seeds weight (100sw) | -0.488** | -0.445** | -0.364** | -0.519** |
| Total Seed weight (tsw) | -0.206 | -0.392** | -0.403** | -0.514** |

Note: *. Significant at α 5%, **. Significant α 1%

***Variance*:** In the variance analysis (Table 2), salinity tolerance characters of hybrids that were not significantly different from the parents indicate a closer similarity to the parent, suggesting the character was dominantly inherited from the parent. Table 2 shows that under low salinity, the hybrids were similar to both parents in the number of leaves, ear length, and ear diameter. Hybrids were more similar to parent E in plant height, stem diameter, leaf length, 100-seed weight, total seed weight, and anthesis timing. Hybrids were similar to parents in ear weight and number of seeds. EB was similar to parent E in silking time, harvest time, and number of seeds, while BE was similar to the parents in leaf width and ear height. BE was similar to parent B in harvest time. Characteristics like total seed weight and 100-seed weight differ between both parents.Under moderate salinity, the hybrids were similar to both parents in ear diameter. Hybrids were more similar to parent E in plant height, stem diameter, number of leaves, leaf length, leaf width, ear height, number of seeds, and 100-seed weight. EB was similar to parent B in ear length and similar to parent E in harvesting time and ear weight. BE was similar to both parents in harvesting time and ear length. Characteristics like anthesis timing, silking, and total seed weight differ between both parents.

**Table 2. Comparison of salinity resistance characteristics of hybrids and parents' maize at Salinity Stress.**

| Character | EC (dS/m) | EB | BE | E | B |
|---|---|---|---|---|---|
| Plant height | 3 | 105.15d | 100.42cd | 102.25cd | 78.68bc |
| | 6 | 85.05bcd | 70.04b | 88.20bcd | 28.31a |
| Stem | 3 | 120.07c | 100.90bc | 94.72bc | 76.18b |
| diameter | 6 | 85.55bc | 68.80b | 69.15b | 15.68a |
| Number of | 3 | 98.81c | 90.34bc | 98.74c | 73.87bc |
| leaves | 6 | 76.85bc | 64.94b | 66.25b | 16.67a |
| Leaf length | 3 | 111.63d | 98.30cd | 116.23d | 70.80bc |
| | 6 | 80.50bc | 64.64b | 54.49b | 18.69a |
| Leaf width | 3 | 132.38c | 90.14b | 91.70b | 80.91b |
| | 6 | 66.98b | 57.95b | 57.58b | 18.18a |
| Ear height | 3 | 129.94c | 90.11b | 94.69b | 79.60b |
| | 6 | 71.69b | 60.33b | 62.00b | 18.94a |
| Anthesis | 3 | 51.70a | 54.90ab | 51.50a | 59.85cd |
| time | 6 | 57.55bc | 57.75bc | 51.70a | 61.90d |
| Silking time | 3 | 53.10a | 57.80bc | 53.10a | 64.00de |
| | 6 | 59.80c | 61.75cd | 54.15ab | 67.75e |
| Harvesting | 3 | 85.00abc | 87.50cd | 84.45ab | 88.30d |
| time | 6 | 84.20a | 87.20bcd | 83.25a | 89.30d |
| Ear length | 3 | 96.67d | 98.84d | 94.00cd | 92.05bcd |
| | 6 | 73.94a | 84.69abc | 87.26bcd | 81.63ab |
| Ear diameter | 3 | 99.85 | 99.87 | 99.89 | 99.97 |
| | 6 | 100.08 | 100.09 | 100.21 | 100.33 |
| Ear weight | 3 | 36.32de | 42.66e | 20.41bc | 26.55cd |
| | 6 | 20.04bc | 28.56cd | 13.36ab | 6.32a |
| Number of | 3 | 164.50cde | 218.30e | 122.80bc | 190.90de |
| seeds | 6 | 117.20bc | 148.85bcd | 89.65ab | 39.30a |
| 100 seeds | 3 | 18.25e | 16.92e | 13.46d | 8.28b |
| weight | 6 | 11.10bcd | 12.26cd | 9.82bc | 3.32a |
| Total seeds | 3 | 30.05d | 33.54d | 16.56bc | 18.35bc |
| weight | 6 | 15.20bc | 21.56c | 10.40ab | 4.12a |

Notes: Numbers followed by the same letters on the rows and columns in same characters, not significantly different at DMRT 5%.

***Heterosis*:** Heterosis indicates that hybrids perform better than the average parent or the best parent. The heterosis value is expected to be positive in the character related to crop production and negative in harvest and flowering time. The results of heterosis analysis (Table 3) at low salinity showed that EB hybrids generally performed better than BE based on positive or better average heterosis values such as plant height, stem diameter, ear weight, seed count, and total seed weight. The heterosis value of the best parent EB also showed more positive values than BE. Heterosis of anthesis, silking, and harvest time characteristics were negative in both hybrids, indicating a decrease in salinity resistance compared to the two parents. At high salinity, EB hybrids are also better than BE, which is characterized by heterosis of mid and best parents with many positive values. The heterosis of anthesis and silking time characters in EB hybrids showed that the

**Table 3. Heterosis percentage of salinity resistance.**

| Characters | EC = 3 dS/m | | | | EC = 6 dS/m | | | |
|---|---|---|---|---|---|---|---|---|
| | mid parent | | best parent | | mid parent | | best parent | |
| | EB | BE | EB | BE | EB | BE | EB | BE |
| Plant height | 3.84 | 3.33 | -8.16 | -8.60 | 33.45 | 22.61 | 4.15 | -4.30 |
| Stem diameter | 36.91 | 15.09 | 35.16 | 13.61 | 35.49 | 26.53 | 26.10 | 17.76 |
| Number of leaves | 2.10 | 10.89 | -9.27 | -1.47 | 6.41 | 5.78 | -25.50 | -25.94 |
| Leaf length | 7.45 | 7.38 | -2.04 | -2.10 | 49.95 | 21.91 | 14.51 | -6.90 |
| Leaf width | -25.41 | 8.88 | -35.29 | -5.55 | 3.63 | 21.46 | -25.41 | -12.58 |
| Ear height | 19.20 | 23.98 | 4.70 | 8.89 | 98.22 | 36.90 | 45.59 | 0.55 |
| Anthesis time | -1.34 | -4.47 | -1.71 | -4.82 | 7.77 | -1.38 | 6.59 | -2.47 |
| Silking time | -1.74 | -4.01 | -2.42 | -4.67 | 6.50 | -1.30 | 5.27 | -2.44 |
| Harvesting time | -0.17 | -0.70 | -0.42 | -0.94 | -0.97 | -0.89 | -1.98 | -1.91 |
| Ear length | 11.55 | -15.33 | -4.51 | -27.52 | 70.85 | 17.10 | 18.17 | -19.00 |
| Ear diameter | 20.36 | 9.40 | 5.47 | -4.13 | 55.26 | 29.29 | 0.48 | -16.33 |
| ear weight | 49.11 | 3.40 | 37.24 | -4.83 | 77.15 | 49.08 | 15.63 | -2.69 |
| Number of seeds | 40.52 | 18.09 | 26.77 | 6.53 | 101.69 | 62.21 | 23.72 | -0.50 |
| 100 seeds weight | 10.63 | -4.37 | 3.05 | -10.92 | 16.67 | 20.05 | -13.98 | -11.49 |
| Total Seed weight | 53.39 | 4.44 | 44.37 | -1.70 | 76.83 | 52.97 | 16.34 | 0.64 |

**Table 4. Gene action of salinity tolerance index (based on dominance degree).**

| Characters | Best Parent | EC = 3 dS/m | | | | Best Parent | EC = 6 dS/m | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | EB | | BE | | | EB | | BE | |
| Plant height | E | 0.29 | PD+ | 1.19 | OD+ | E | 0.26 | PD+ | 0.80 | PD+ |
| Stem diameter | E | 28.41 | OD+ | 4.77 | OD+ | E | 11.62 | OD+ | 3.56 | OD+ |
| Number of leaves | E | 0.17 | PD+ | 0.15 | PD+ | E | 0.87 | PD+ | 0.13 | PD+ |
| Leaf length | E | 0.77 | PD+ | 1.61 | OD+ | E | 0.76 | PD+ | 0.71 | PD+ |
| Leaf width | E | -1.66 | OD- | 0.09 | PD+ | E | 0.58 | PD+ | 0.55 | PD+ |
| Ear height | E | 1.39 | OD+ | 2.72 | OD+ | E | 1.73 | OD+ | 1.02 | OD+ |
| Anthesis time | E | -3.57 | OD- | 6.98 | OD+ | B | -11.88 | OD- | -1.24 | OD- |
| Silking time | E | -2.49 | OD- | 5.56 | OD+ | B | -5.74 | OD- | -1.11 | OD- |
| Harvesting time | E | -0.71 | PD- | -0.94 | PD- | B | -2.84 | OD- | -0.86 | PD- |
| Ear length | E | 0.69 | PD+ | 1.59 | OD+ | E | -0.91 | PD- | 0.38 | PD+ |
| Ear diameter | E | 1.44 | OD+ | 1.01 | OD+ | E | 0.67 | PD+ | 0.54 | PD+ |
| ear weight | E | 5.68 | OD+ | 1.45 | OD+ | E | 0.39 | PD+ | 0.92 | PD+ |
| Number of seeds | E | 3.74 | OD+ | 1.61 | OD+ | E | 1.67 | OD+ | 0.99 | PD+ |
| 100 seeds weight | E | 1.45 | OD+ | 0.47 | PD+ | E | -0.59 | PD- | 0.56 | PD+ |
| Total Seed weight | E | 8.54 | OD+ | 1.48 | OD+ | E | 0.71 | PD+ | 1.02 | OD+ |

Note: PD, partial dominance. OD, overdominance

salinity resistance level was better than the average of both the parent and the best parent.

***Gene action (degree of dominance)*:** The degree of dominance in hybrids can describe the combination interaction, i.e., how strongly the dominant allele influences the recessive gene to produce a specific phenotype. The phenotype of descent can be intermediate of both parents (no dominance), closer to one parent (partial dominance), similar to one of the parents (dominance), or beyond either higher or lower parent (overdominance). Positive dominant degree values indicate the dominance of the best parents, and negative values indicate the opposite. Table 4 shows that most of the salinity resistance characteristics of the hybrid are both at low salinity and medium salinity closer to parent E. At low salinity levels, the salinity resistance character of parent E showed partial dominance in the EB hybrid, namely in the character of plant height, number of leaves, anthesis time, silking, harvest, and ear length. In the BE hybrid, it is seen in the characteristics of the number of leaves, the width of the leaves, the harvest time, and the weight of one hundred seeds. The salinity resistance character of parent B to EB maize can be seen in the leaf width character. The dominant over value indicates that the character is closer to the parent E even though the interaction resulting from gene recombination shows a greater value than the two parents. At high salinity levels, the salinity resistance characteristic of parent E shows

**Table 5. Gene Action of Salinity Tolerance Index (based on gen additive and interaction).**

| Characters | Skewness | | | | Kurtosis | | | |
|---|---|---|---|---|---|---|---|---|
| | EC = 3 dS/m | | EC = 6 dS/m | | EC = 3 dS/m | | EC = 6 dS/m | |
| | EB | BE | EB | BE | EB | BE | EB | BE |
| Plant height | -0.68 D | 0.26 C | -0.03 D | -1.32 D | 0.90 P | -1.34 P | 2.64 P | 3.15 L |
| Stem diameter | -0.49 D | -1.13 D | -1.47 D | -0.32 D | -1.00 P | 1.24 P | 2.71 P | -0.91 P |
| Number of leaves | -0.05 D | -1.35 D | -1.51 D | -2.46 D | -1.19 P | 1.74 P | 2.33 P | 8.79 L |
| Leaf length | -2.41 D | 0.17 C | -1.66 D | -0.95 D | 5.36 L | -0.11 P | 1.58 P | -0.75 P |
| Leaf width | -2.16 D | -0.25 D | -1.35 D | -0.98 D | 4.76 L | -1.16 P | 0.53 P | -0.69 P |
| Ear height | -1.18 D | -0.79 D | -0.65 D | -0.37 D | 1.43 P | 2.33 P | -0.25 P | -1.13 P |
| Anthesis time | 0.62 C | -0.05 D | 0.32 C | -0.38 D | 0.00 P | -0.53 P | -1.70 P | -1.12 P |
| Silking time | 1.66 C | 0.31 C | 0.30 C | -0.27 D | 4.05 L | -0.89 P | -1.67 P | -1.48 P |
| Harvesting time | -1.48 D | -1.70 D | -0.83 D | -1.27 D | 2.82 P | 1.13 P | 0.48 P | -0.26 P |
| Ear length | -0.36 D | 0.02 C | -1.20 D | -0.80 D | -0.01 P | -0.67 P | 0.14 P | -0.81 P |
| Ear diameter | 0.40 C | -0.52 D | -0.78 D | -1.12 D | -1.36 P | 0.07 P | 0.05 P | -0.61 P |
| ear weight | 0.74 C | -0.02 D | 0.94 C | -0.12 D | -0.02 P | -1.32 P | 1.01 P | -1.13 P |
| Number of seeds | 0.66 C | 0.31 C | 1.05 C | -0.28 D | 0.28 P | -0.14 P | 0.56 P | -1.31 P |
| 100 seeds weight | -0.49 D | -0.42 D | -0.23 D | -0.75 D | -0.04 P | 0.67 P | 0.81 P | -0.81 P |
| Total Seed weight | 0.60 C | 0.04 C | 1.16 C | 0.24 C | 0.01 P | -1.32 P | 1.30 P | -0.81 P |

Note: D, additive gene action with duplicate epistasis effects. C, additive gene action with complementary epistasis effects. P, platykurtic distribution: the character is controlled by many genes. L, leptokurtic distribution: the character is controlled by a few genes.

partial dominance in most of the hybrid characters of EB and BE. The dominance of part of parent B is seen in the character of the length of the ear and the weight of one hundred seeds. Over dominant in the character of stem diameter and ear height. The change in dominance showed a change in gene action in the face of increased salinity stress levels.

***Gene action (gene interaction and controlling)*:** Phenotypes can be caused by additive and epistasis gene action. The phenotype of additive gene action is due to the summation of each allele without interaction with other alleles (allelic or non-allelic interactions), while in epistasis gene action, the phenotype is determined by the interaction of alleles from different loci (Roy, 2000; Sujiprihati et al., 2007; Barrell et al., 2010). Table 5 shows that the salinity resistance character formed from several parameters due to the additive gene action with duplicate epistasis effects (code D) and complementary (C). In moderate stress, EB and BE maize showed Additive gene action with complementary epistasis effects. In EB maize, the effect of complementary epistasis was seen in the characters of anthesis time, silking time, ear diameter, ear weight, number of seeds, and total grain weight. In BE maize, the effect of complementary epistasis was seen in the characteristics of plant height, leaf length, silking time, ear length, number of seeds, and total weight of seeds. At moderate stress, there is a change in gene action in some characters, which were previously complementary to duplicates. EB occurs in the ear diameter character, while in BE occurs in almost all of these characters except the total weight of the seed. The change in gene action from complementary to duplicate is thought to be related to changes in gene activity related to changes in salinity stress levels.

The expression of salinity resistance phenotypes in maize characters is generally controlled by genes, based on the kurtosis values which are generally platykurtic, showing that they are controlled by many genes. Leaf length, leaf width, and silking time of hybrid E changed from leptokurtic to platykurtic, meaning that the resistance character was controlled by a few genes at low salinity and then by many genes at medium salinity. Plant height and leaves number of hybrid BE changed from being controlled by many genes to a few genes.

## DISCUSSION

The result of this study illustrates the inheritance patterns of salinity tolerance character in the F1 Hybrids derived from a crossbreed of salinity resistance (parent ‘E’) and sensitive (parent ‘B’) maize. Based on the results of the correlation test (Table 1), there was an increase in salinity resistance in hybrids compared to the parents, aligning with the goals of plant breeding to enhance the quality (Acquaah, 2015; Jackson et al., 1996; Witcombe et al., 2005). An increase in salinity resistance may describe gene recombination from both parents and its interactions, resulting in a character that is more tolerant than both or one of the parents. Based on ANOVA analysis, resistance character of hybrids in many levels of salinity also showed a similarity with one of the parents or both of them, indicating the dominance of one of the parents, additive or non-additive genetic effects (John et al., 2024; Lima et al., 2019; Pea et al., 2008).

Under low salinity stress, salinity resistance characters of hybrids were similar to both parents, suggesting additive genes(Procházková et al., 2013; Rohman et al., 2019). STI of plant height, stem diameter and flowering time were more similar to the resistant parent E, while ear weight and seed number characters were more similar to the sensitive parent B. It indicates partial dominance of salinity resistance characters from the resistant parent. The indication was reinforced by the heterosis value of hybrid EB, showing a positive value for yield-related characters, better than hybrid BE. Degree of dominance value of hybrids also confirmed positive partial dominance and over dominance of salinity resistance characters towards the resistant parents E. This suggests cytoplasmic or maternal effects that influenced the expression of resistance characters (Rasekh, 2024; Zhang et al., 2023). Under moderate salinity stress, based on Anova, salinity resistance characters of hybrids tended to be more similar to resistant parent E, the dominance of salinity resistance alleles from the parent both partially dominance and overdominance. Interestingly, there were some changes in heterosis value (*hMP* and *hHP*) of salinity resistance characters along with increasing of salinity stress level, from positive to negative and vice versa, such as *hMP* of EB flowering time, *hHP* of EB plant height, *hHP* of BE number of seeds and many others. The change also happened in degree of dominance from overdominance to partial dominance such as EB plant height. It's changing suggest complex structure and interactions of genes that responsible to deal with increasing of salinity stress (Andjelkovic & Thompson, 2006; Fang, Shan, et al., 2024; Fu et al., 2012; Qing et al., 2009).

The complex interaction of gene associated with salinity stress was also confirmed in the changing of gene action. The change of gene action in different level could show different responses of plant in stress (Annor & Badu-Apraku, 2016; Badu-Apraku et al., 2016; Monforte et al., 1999; Wibowo, 2018). Under low salinity stress, salinity resistance character of BE plant height formed by additive gene with complementary epistasis and controlled by many genes but changed to duplicate and controlled by few genes under moderate salinity stress. Different cases happened in the salinity character of BE ear length. It changes from additive gene with complementary epistatis to duplicate epistasis, but it was still controlled by many genes. Salinity character of EB ear length just changes in genes controlling from few to many.

***Conclusion*:** The results showed that the inheritance of salinity resistance characteristics in hybrid maize involved the dominance of salinity resistant parents E. The dominance could be partially dominance and over dominance. There are heterosis effects on hybrids show genetic improvement. The salinity resistance characters formed by additive genes with complementary and duplicate epistasis and controlled by many and few genes that expressed the complex structure and interactions.

***CRediT author statement*:** K.P.W. Sukma, designed, completed the experiments and prepared the draft, B.S. Daryono, D. Rachmawati, Purnomo reviewed and finalized the draft.

***Conflict of interest*:** The authors declare no conflict of interest.

***Acknowledgement*:** The Author wants to thank to Universitas Islam Madura, Universitas Gadjah Mada for the support and facilitation during this research

***Funding*:** This work was supported by research grants from Universitas Islam Madura and Universitas Gadjah Mada.

***Availability of data and material*:** Data is available upon request from the corresponding author.

***Consent for publication*:** All authors submitted consent to publish this research article in JGIAS.

***SDGs addressed*:** Zero Hunger

***Policy referred*:** Breeding Programs Focused on Salinity Resistance; Investment in Hybrid Maize Development; Salinity Stress Screening as a Standard Procedure

***Publisher's note*:** All claims stated in this article are exclusively those of the authors and do not necessarily represent those of their affiliated organizations or those of the publisher, the editors, and the reviewers. Any product that may be evaluated/assessed in this article or claimed by its manufacturer is not guaranteed or endorsed by the publisher/editors.

## REFERENCES

Acquaah, G. (2015). Conventional plant breeding principles and techniques. *Advances in Plant Breeding Strategies: Breeding, Biotechnology and Molecular Tools*, 115-158.

Alghamdi, S. A. (2024). Drought and salinity effects on plant growth: A comprehensive review. SABRAO *Journal of Breeding & Genetics*, *56*(6), 2331-2340.

Aliu, S., Rusinovci, I., Fetahu, S., Gashi, B., Simeonovska, E., & Rozman, L. (2015). The effect of salt stress on the germination of maize (Zea mays L.) seeds and photosynthetic pigments. *Acta Agriculturae Slovenica*, *105*(1), 85-94. https://doi.org/10.14720/aas.2015.105.1.09

Amzeri, A., Indradewa, D., Daryono, B. S., & Rachmawati, D. (2011). Phenetic and genetic relationships among madura local maize (*Zea mays* L.) revealed by morphological characters and RAPD markers. *Biota*, *16*, 227-235.

Andjelkovic, V., & Thompson, R. (2006). Changes in gene expression in maize kernel in response to water and salt stress. *Plant Cell Reports*, *25*, 71-79.

Annor, B., & Badu-Apraku, B. (2016). Gene action controlling grain yield and other agronomic traits of extra-early quality protein maize under stress and non-stress conditions. *Euphytica*, *212*, 213-228.

Arif, A. (2021). *Merakit Padi Agar Toleran Salinitas* . Https://Www.Kompas.Id/Baca/Ilmu-Pengetahuan-Teknologi/2021/03/29/Merakit-Padi-Agar-Toleran-Salinitas/.

Aslam, M., Sohail, Q., Maqbool, M. A., Zaman, Q. U., & Ahmed, Z. (2015). Combining ability analysis and genetic inheritance of salt tolerance indicators in maize (*Zea mays*) following diallel mating design. *International Journal of Agriculture and Biology*, *17*, 523-530. https://doi.org/10.17957/IJAB/17.3.14.472

Badu-Apraku, B., Fakorede, M. A. B., Talabi, A. O., Oyekunle, M., Akaogu, I. C., Akinwale, R. O., Annor, B., Melaku, G., Fasanmade, Y., & Aderounmu, M. (2016). Gene action and heterotic groups of early white quality protein maize inbreds under multiple stress environments. *Crop Science*, *56*, 183-199.

Balkrishna, R. A., & Shankarrao, S. S. (2013). In vitro screening and molecular genetic markers associated with salt tolerance in maize. *African Journal of Biotechnology*, *12*, 4251-4255. https://doi.org/10.5897/ajb2012.2992

Barrell, P. J., Meiyalaghan, S., Jacobs, J. M. E., & Conner, A. J. (2013). Applications of biotechnology and genomics in potato improvement. *Plant Biotechnology Journal*, *11*, 907-920.

Bosnic, P., Bosnic, D., Jasnic, J., & Nikolic, M. (2018). Silicon mediates sodium transport and partitioning in maize under moderate salt stress. *Environmental and Experimental Botany*, *155*, 681-687. https://doi.org/10.1016/j.envexpbot.2018.08.018

Cao, Y., Liang, X., Yin, P., Zhang, M., & Jiang, C. (2019). A domestication-associated reduction in K + -preferring HKT transporter activity underlies maize shoot K + accumulation and salt tolerance. *New Phytologist*, *222*, 301-317. https://doi.org/10.1111/NPH.15605

Carpıcı, E. B., Celık, N., & Bayram, G. (2009). Effects of salt stress on germination of some maize (*Zea mays* L.) cultivars. *African Journal of Biotechnology*, *8*, 4918-4922. http://www.academicjournals.org/AJB

Coca, L. I. R., González, M. T. G., Unday, Z. G., Hernández, J. J., Rodríguez Jáuregui, M. M., & Fernández Cancio, Y. (2023). Effects of sodium salinity on rice (*Oryza sativa* L.) cultivation: A review. *Sustainability*, *15*, 1804.

Cui, D., Wu, D., Somarathna, Y., Xu, C., Li, S., Li, P., Zhang, H., Chen, H., & Zhao, L. (2015). QTL mapping for salt tolerance based on snp markers at the seedling stage in maize (*Zea mays* L.). *Euphytica*, *203*, 273-283. https://doi.org/10.1007/S10681-014-1250-X

Dachlan, A., Kasim, N., & Sari, A. K. (2013). Uji ketahanan salinitas beberapa varietas jagung (*Zea mays* L.) dengan menggunakan agen seleksi NaCl. *Biogenesis: Jurnal Ilmiah Biologi*, *1*, 9-17.

Dasriani, D., Zubaidah, S., & Kuswantoro, H. (2020). Inheritance of morphological characters of soybean leaves, pods, and seeds. *AIP Conference Proceedings*, *2231*.

David, J., & Abdurrahman, T. (2021). Growth Response of Soybeans (Glycinemax) to Ameliorants in Saline Soil. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, *49*, 259-265.

Dehnavi, A. R., Zahedi, M., & Piernik, A. (2024). Understanding salinity stress responses in sorghum: exploring genotype variability and salt tolerance mechanisms. *Frontiers in Plant Science*, *14*, 1296286.

Ding, D., Zhang, L., Wang, H., Liu, Z., Zhang, Z., & Zheng, Y. (2009). Differential expression of miRNAs in response to salt stress in maize roots. *Annals of Botany*, *103*, 29-38. https://doi.org/10.1093/aob/mcn205

Effa, P. O., Ondobo, M. L., Djocgoue, P. F., & Niemenak, N. (2016). Heterosis and heritability estimates of purine alkaloids and polyphenols in cocoa. *African Crop Science Journal*, *24*, 235-246.

Fang, H., Fu, X., Ge, H., Jia, M., Ji, J., Zhao, Y., Qu, Z., Cui, Z., Zhang, A., Wang, Y., Li, P., & Wang, B. (2024). Genetic analysis and candidate gene identification of salt tolerance-related traits in maize. *Journal of Integrative Agriculture*, *23*, 2196-2210. https://doi.org/10.1016/J.JIA.2024.02.009

Fang, H., Shan, T., Gu, H., Chen, J., Qi, Y., Li, Y., Saeed, M., Yuan, J., Li, P., & Wang, B. (2024). Identification and characterization of ACR gene family in maize for salt stress tolerance. *Frontiers in Plant Science*, *15*, 1381056.

Fatikhasari, Z., Lailaty, I. Q., Sartika, D., & Ubaidi, M. A. (2022). Viability and seed vigour of Peanut (*Arachis hypogaea* L.), Mung Bean (*Vigna radiata* (L.) R. Wilczek), and Corn (*Zea mays* L.) at different temperatures and osmotic pressures. *Jurnal Ilmu Pertanian Indonesia*, *27*, 7-17.

Fu, J., Zhang, D.-F., Liu, Y.-H., Ying, S., Shi, Y.-S., Song, Y.-C., Li, Y., & Wang, T.-Y. (2012). Isolation and characterization of maize PMP3 genes involved in salt stress tolerance. *PloS One*, *7*, e31101.

Gama, P. B. S., Inanaga, S., Tanaka, K., & Nakazawa. (2007). Physiological response of common bean (*Phaseolus vulgaris* L.) seedlings to salinity stress. *African Journal of Biotechnology*, *6*, 79-088. http://www.academicjournals.org/AJB

Hailu, B., & Mehari, H. (2021). Impacts of soil salinity/sodicity on soil-water relations and plant growth in dry land areas: A review. *Journal of Natural Science Resources 12*(3), 1-10.

Han, Y., & Wang, Q. (2023). Feature and mechanism analysis of dispersive soil disintegration impacted by soil water content, density, and salinity. *European Journal of Soil Science*, *74*, e13353.

Hoque, M. M. I., Jun, Z., Guoying, W., Muhebbullah, M., & Hoque, I. (2015). Evaluation of salinity tolerance in maize (*Zea mays* L.) genotypes at seedling stage. *Journal of BioScience Biotechnology 4*, 39-49. http://www.jbb.uni-plovdiv.bg

Hussain, K., Majeed, A., Zulfikar, S., Bhutto, A., Nawaz, K., Farrukh Nisar, M., Khatoon, T., & Farrukh Nisar, M. (2010). mllmlml View project hepatotoxicity View project Morphological Variations in Maize (*Zea mays* L.) Under Different Levels of Nacl at Germinating Stage. *World Applied Sciences Journal*, *8*, 1294-1297. https://www.researchgate.net/publication/215564829

Ismail, A. (2007, August). Rice Tolerance to salinity and other problem soils: Physiological Aspects and Relevance breeding. *IRRI Lecture in Rice Breeding Course*.

Jackson, P., Robertson, M., Cooper, M., & Hammer, G. (1996). The role of physiological understanding in plant breeding; from a breeding perspective. *Field Crops Research*, *49*, 11-37.

Jiang, Z., Song, G., Shan, X., Wei, Z., Liu, Y., Jiang, C., Jiang, Y., Jin, F., & Li, Y. (2018). Association Analysis and Identification of ZmHKT1;5 Variation With Salt-Stress Tolerance. *Frontiers in Plant Science*, *9*. https://doi.org/10.3389/fpls.2018.01485

John, B. A., Kachapur, R. M., Naidu, G., Talekar, S. C., Rashid, Z., Vivek, B. S., Patne, N., Salakinkop, S. R., & Prema, G. U. (2024). Maternal effects, reciprocal differences and combining ability study for yield and its component traits in maize (*Zea mays* L.) through modified diallel analysis. *PeerJ*, *12*, e17600. https://doi.org/10.7717/peerj.17600

Khayatnezhad, M., & Gholamin, R. (2011). Effects of salt stress levels on five maize (*Zea mays* L.) cultivars at germination stage. *African Journal of Biotechnology*, *10*, 12909-12915. https://doi.org/10.5897/ajb11.1568

Li, L., Gu, W., Zhang, L., Li, C., Chen, X., Qian, C., Wang, Z., Li, W., Zuo, S., & Wei, S. (2020). Exogenous 2-(3,4-Dichlorophenoxy) triethylamine alleviates salinity stress in maize by enhancing photosynthetic capacity, improving water status and maintaining K+/Na+homeostasis. *BMC Plant Biology*, *20*. https://doi.org/10.1186/s12870-020-02550-w

Lima, V. J. de, Amaral Júnior, A. T. do, Kamphorst, S. H., Bispo, R. B., Leite, J. T., Santos, T. de O., Schmitt, K. F. M., Chaves, M. M., Oliveira, U. A. de, & Santos, P. H. A. D. (2019). Combined dominance and additive gene effects in trait inheritance of drought-stressed and full irrigated popcorn. *Agronomy*, *9*, 782.

Meena, H. N., Yadav, R. S., Jain, N. K., & Meena, M. S. (2022). Sodium accumulation trend in the different quality seed, cultivars, and yield potential of peanut under salinity stress. *Journal of Plant Nutrition*, *45*, 3129-3144.

Mohanavelu, A., Naganna, S. R., & Al-Ansari, N. (2021). Irrigation induced salinity and sodicity hazards on soil and groundwater: An overview of its causes, impacts and mitigation strategies. *Agriculture*, *11*, 983.

Monforte, A. J., Asins, M. J., & Carbonell, E. A. (1999). Salt tolerance in Lycopersicon spp. VII. Pleiotropic action of genes controlling earliness on fruit yield. *Theoretical and Applied Genetics*, *98*, 593-601.

Nawaz, A., Haseeb, A., Malik, H., Ali, Q., & Malik, A. (2020). Genetic association among morphological traits of *Zea mays* seedlings under salt stress. *Biol Clin Sci Res J*, *21*.

Ozturk, M., Turkyilmaz Unal, B., García-Caparrós, P., Khursheed, A., Gul, A., & Hasanuzzaman, M. (2021). Osmoregulation and its actions during the drought stress in plants. *Physiologia Plantarum*, *172*, 1321-1335.

Pavuluri, S., Jambhekar, V., & Hommel, J. (2014). *Kinetic approach for modeling salt precipitation in porous-media*. Incomplete??

Pea, G., Ferron, S., Gianfranceschi, L., Krajewski, P., & Pe, M. E. (2008). Gene expression non-additivity in immature ears of a heterotic F1 maize hybrid. *Plant Science*, *174*, 17-24.

Petr, F. C., & Frey, K. J. (1966). Genotypic Correlations, Dominance, and Heritability of Quantitative Characters in Oats 1. *Crop Science*, *6*, 259-262.

Procházková, D., Sairam, R. K., Lekshmy, S., & Wilhelmová, N. (2013). Differential response of a maize hybrid and its parental lines to salinity stress. *Czech Journal of Genetics and Plant Breeding*, *49*, 9-15.

Utra, E. T. S., & Indradewa, D. (2011). *Perubahan iklim dan ketahanan pangan nasional*. Fakultas Pertanian, Universitas Gadjah Mada. http://www.faperta.ugm.ac.id/dies/eka_prof_didik.php

Qing, D.-J., Lu, H.-F., Li, N., Dong, H.-T., Dong, D.-F., & Li, Y.-Z. (2009). Comparative profiles of gene expression in leaves and roots of maize seedlings under conditions of salt stress and the removal of salt stress. *Plant and Cell Physiology*, *50*, 889-903.

Ramazan, S., Nazir, I., Yousuf, W., & John, R. (2023). Environmental stress tolerance in maize (*Zea mays*): role of polyamine metabolism. *Functional Plant Biology*, *50*, 85-96. https://doi.org/10.1071/FP21324

Rasekh, A. (2024). Increased Stress Tolerance in Plants as a Result of Parental Effects. In *Molecular Dynamics of Plant Stress and its Management* (pp. 51-65). Springer.

Rohman, M. M., Hossain, M. G., Omy, S. H., Methela, N. J., & Molla, M. R. (2019). Evaluation of diallel crosses of maize at multilocation (*Zea mays* L.) for saline tolerance. *Journal of Cereals and Oilseeds*, *10*, 29-42.

Roy, D. (2000). *Plant breeding: Analysis and exploitation of variation*. Alpha Science Int'l Ltd.

Seleiman, M. F., Aslam, M. T., Alhammad, B. A., Hassan, M. U., Maqbool, R., Chattha, M. U., Khan, I., Gitari, H. I., Uslu, O. S., & Roy, R. (2022). Salinity stress in wheat: effects, mechanisms and management strategies. *Phyton (0031-9457)*, *91*.

Shahid, S. A., Zaman, M., & Heng, L. (2018). Introduction to Soil Salinity, Sodicity and Diagnostics Techniques. In *Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Related Techniques* (pp. 1-42). Springer International Publishing. https://doi.org/10.1007/978-3-319-96190-3_1

Shtereva, L. A., Vassilevska-Ivanova, R. D., & Karceva, T. V. (2015). Effect of salt stress on some sweet corn (Zea mays L. var. saccharata) genotypes. *Archives of Biological Sciences*, *67*, 993-1000. https://doi.org/10.2298/ABS150121062S

Singh, A., Agrawal, S., Rajput, V. D., Minkina, T., Rensing, C., Elshikh, M. S., Zhao, Y., Alexiou, A., Papadakis, M., & Ghazaryan, K. (2025). Biogenic nanoparticles for managing salinity stress-related crop and environmental risks: realistic applications and challenges. *Discover Sustainability*, *6*, 120.

Sousa, G. G. D. E., Sousa, H. C., Santos, M. A. X. F. D. O. S., Lessa, C. I. N., & Gomes, S. P. (2022). Saline water and nitrogen fertilization on leaf composition and yield of corn. *Revista Caatinga*, *35*, 191-198.

Sujiprihati, S., Yunianti, R., Syukur, M., & Undang, U. (2007). Estimation of heterosis and combining ability for yield components of six Chili (*Capsicum annuum* L.) genotypes in full diallel crosses. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, *35*.Pages???

Sukma, K. P. W., Daryono, B. S., Purnomo, & Suprapti, I. (2018). Salinity resistance of seven varieties of Madura corn on early stage of growth. *4th International Conference on Food and Agriculture Resources (FANRes 2018). 4th International Conference on Food and Agriculture Resources (FANRes 2018). Atlantis Press: Advances in Engineering Research*, *172*, 181-184.

Sukma, K. P. W., Daryono, B. S., Rachmawati, D., & Purnomo, P. (2025). Vegetative characters of salt resistance and sensitive corn (*Zea mays* L.) under salinity stress. *AIP Conference Proceedings*, *3186*.

Suprianto, H., Ravaie, E., Irianto, S. G., Susanto, R. H., Schultz, B., Suryadi, F. X., & van Den Eelaart, A. (2010). Land and water management of tidal lowlands: Experiences in Telang and Saleh, South Sumatra. *Irrigation and Drainage*, *59*, 317-335. https://doi.org/10.1002/ird.460

Tahir, N. A., & Maeruf, M. S. (2016). Assessment of salinity tolerance and SSR profile differentiation in nine maize genotypes (*Zea mays* L). *Maydica*, *61*. Pages?? http://www.maizegdb.org/data_

Utama, M. Z. H., & Haryoko, D. W. (2020). Mekanisme Adaptasi Jagung terhadap Cekaman NaCl: Pola Serapan Anion dan Kation. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, *47*, 255-261. https://doi.org/10.24831/jai.v47i3.25439

Wibowo, F. (2018). Physiological performance of the soybean crosses in salinity stress. *IOP Conference Series: Earth and Environmental Science*, *122*, 012029.

Witcombe, J. R., Joshi, K. D., Gyawali, S., Musa, A. M., Johansen, C., Virk, D. S., & Sthapit, B. R. (2005). Participatory plant breeding is better described as highly client-oriented plant breeding. I. Four indicators of client-orientation in plant breeding. *Experimental Agriculture*, *41*, 299-319.

Xing, X., Feng, H., Jiao, S., Xia, T., Li, D., Zhao, F., & Wang, W. (2025). Soil water, salt, and microplastics interact during migration: Performance and mechanism. *Geoderma*, *455*, 117229.

Yahaya, S. M., Mahmud, A. A., Abdullahi, M., & Haruna, A. (2023). Recent advances in the chemistry of nitrogen, phosphorus and potassium as fertilizers in soil: A review. *Pedosphere*, *33*, 385-406.

Yang, G., Zhou, R., Tang, T., Chen, X., Ouyang, J., He, L., Li, W., Chen, S., Guo, M., Li, X., Zhong, C., & Shi, S. (2011). Gene expression profiles in response to salt stress in *Hibiscus tiliaceus*. *Plant Molecular Biology Reporter*, *29*, 609-617.

Zhang, M., Hu, Y., Han, W., Chen, J., Lai, J., & Wang, Y. (2023). Potassium nutrition of maize: Uptake, transport, utilization, and role in stress tolerance. *The Crop Journal*, *11*, 1048-1058.

Zörb, C., Stracke, B., Tramnitz, B., Denter, D., Sümer, A., Mühling, K. H., Yan, F., & Schubert, S. (2005). Does H+ pumping by plasmalemma ATPase limit leaf growth of maize (*Zea mays*) during the first phase of salt stress? *Journal of Plant Nutrition and Soil Science*, *168*, 550-557. https://doi.org/10.1002/jpln.200520503.